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Simulating Firing Loads Provides Flexibility, Test Repeatability

The composite armored vehicle (CAV) is an advanced technology demonstrator (ATD) being developed to determine the potential of lightweight composites, composite armor, and integrated signature management technologies in combat vehicles. The goal is to maintain similar ballistic protection while reducing armor weight and structure by 33 percent. A prototype of the rear upper hull (quarter section), which incorporates the gun turret, was constructed to develop manufacturing methods and determine structural characteristics of the hull before building the complete vehicle. The quarter section underwent simulated firing impulse loads at U.S. Army Aberdeen Test Center's (ATC's) firing impulse simulator (FIS) facility.

Imparted structural loads corresponded to the firing of a 105mm gun at various azimuths and elevations. FIS allowed representative dynamic loads to be imparted, rather than static loads, to determine structural response. Instrumentation on the prototype measured accelerations, strains, and displacements, which were compared with computer models. ATC facilitated the comparison between test results and computer models by providing local access to work stations on which computer models could be imported and exercised by the customer.

This immediate feedback allowed the customer, working with ATC personnel, to continually monitor and modify the original test plan. This synergistic effort helped solve problems quickly. Load displacement and load strain data are extremely useful in showing that the design not only meets but well exceeds design load requirements.

Testing of the ATD structure was performed at ATC from October 1995 through March 1996. The test item consisted of a composite specimen mounted to an aluminum test fixture. The full-scale test specimen, measuring approximately 251.5 cm wide, 221 cm long, and 46 cm tall, represented the rear upper hull of the CAV. Several test specimens were constructed for the CAV development program. The specimen used in this test is a complex composite hull section built of epoxy/S-2 glass fabric, carbon graphite fabric, aluminum mesh, ceramic tile, and rubber sheet. Figure 1 illustrates the laminated composite structure. The turret opening is closed out with an aluminum ring that stiffens the top plate, protects the edge of the laminate, and provides a machined surface for turret bearing mounting.

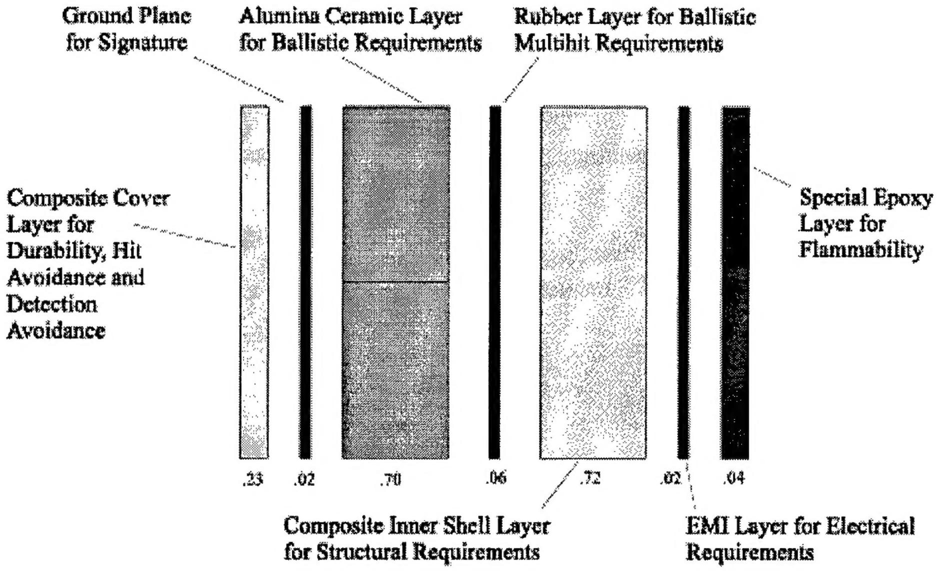

Figure 1. Upper Hull Integrated Structure

A gun carriage built by United Defense Limited Partnership (UDLP) allowed impulse loads to be transmitted into the specimen. An M35 105mm gun system was mounted to the carriage, with a specially modified M35 105mm gun tube fitted with a bumper cushion to accept the impulse loads from the FIS. The carriage was mounted to the test structure with a 152.4-cm (60-inch) Rotek bearing identical to that used on the M2 Bradley Fighting Vehicle(BFV). The complete test item was bolted to the FIS test item positioning platform.

The FIS was developed to test the mechanical and hydraulic components (recoil systems, bearings, seals, etc.) of large-caliber weapon systems without firing live ammunition. It provides the required impulse to the system under test to fully replicate the forces generated during actual firing. The applied impulse load can be tailored to provide different levels of stress to the item (under or over match design limits), allowing more controlled testing. The impulse loads imparted are determined by monitoring the recoil system of the test item and comparing to actual firing results.

The FIS can test large-caliber weapons and weapon systems from 0-85 degrees elevation, delivering a maximum force of 2,600,000 pounds to the test item. The different gun elevations are made possible by an adjustable trunnion height locating system incorporated in the FIS. The FIS operates through a hydraulically propelled impact device similar to a pile driver. The energy imparted to a weapon system during firing is simulated by the kinetic energy of a moving mass (the FIS impact piston) colliding with the muzzle of the gun tube. The weapon dissipates this energy through the recoil system and other parts of the system (i.e. weapon mount, vehicle suspension, elastic

deformation of load bearing structures, etc.). A schematic of the FIS is shown in figure 2.

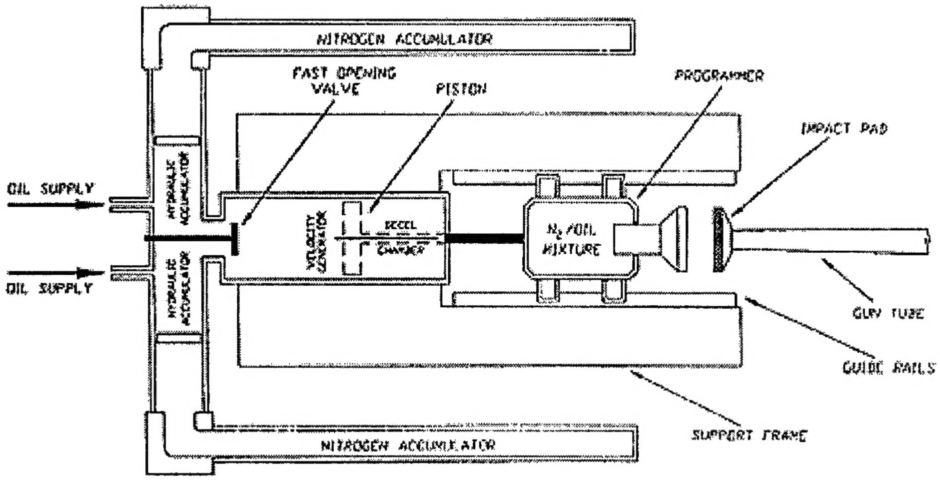

Figure 2. Schematic of the Firing Impulse Simulator

The primary objective of testing was to evaluate the CAV ATD upper-hull design and engineering analysis during simulated gun-firing loads. The testing performed determined structural deflections, stress, and strain in the top plate, in the side wall corners, and around the turret ring closeout. Measured values were provided to the U.S. Army Research Laboratory (ARL) and UDLP for comparison to their design models.

The first test phase consisted of static force trials and FIS impulse load trials. In the static force trials, a horizontal load was applied to the CAV at the top plate of the gun carriage, in three ways: an M88 recovery vehicle, used initially to apply the force; a turn buckle configuration; and a mobile dynamometer. Displacements and strains were measured during each load, through trials with several turret azimuth and gun elevation orientations.

The second phase consisted of low-velocity applied loads to the muzzle while comparing the load calculated from the brake and recuperator pressures with the load measured by the load cell, and FIS impulse load trials with the weapon system at 0 degrees elevation and 180 degrees azimuth. Mathematical calculations determined the maximum trunnion force input from the FIS. Recoil pressures were compared with pressures obtained from the hard stand firing test.

Throughout the dynamic load tests, visual, ultrasonic, and tap tests were conducted to verify structure integrity. At the completion of the last of the 212 cycles, a 100 percent X-ray inspection was conducted. Additional inspections with a tap hammer, ultrasonics using a mobile automated ultrasonic

scanner (MAUS III) system, and thermal imagery by ARL were also conducted.

The calculation of trunnion force for both simulated (cycle No. 205) and live (M456A2 at 63 degrees C) firing is presented as force versus time in figure 3. The plot shows a high correlation in both magnitude and duration of the simulated impulse loads and live firing. Of all the inspection techniques used, only the thermal imagery showed any potential delaminations along one edge.

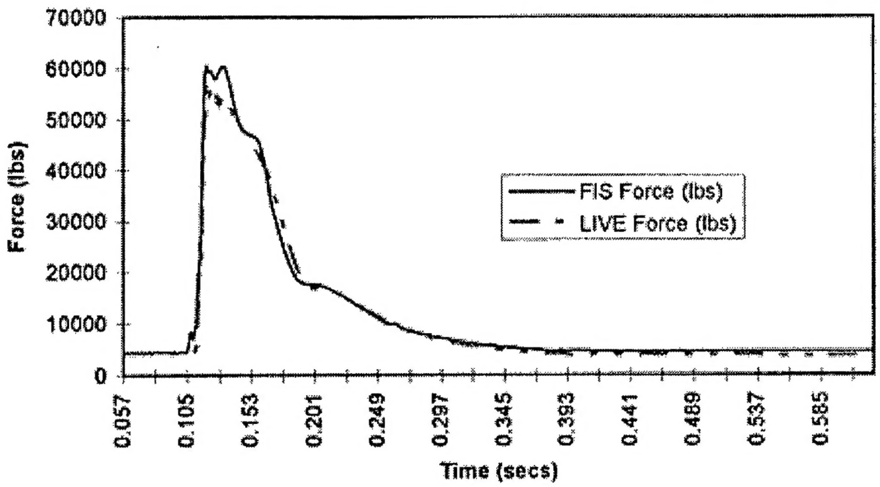

Figure 3. Trunnion Force Comparison M456 Live Round vs. Simulated

The use of the FIS allowed for repeatable, variable, dynamic structure loading not obtainable by actual firing. This simulated firing load allowed for a more precise model verification. The CAV ATD is a true "model" of how the use of simulation and modeling can work hand in hand.

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